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Evaluation of various strain of button mushroom (*Agaricus bisporus* L.) for their cultural, morphological and yield attributes

Pema Wangchu, Tapor Pakpu and Ige Kamduk

Abstract
Agaricus bisporus germplasm consisting of popularly grown strains in India and some other collections was evaluated for identification of parental lines for single spore selection. In the current experiments, seven test strains of *Agaricus bisporus* were used, and they were cultivated on five different solid media. After 21 days of inoculation, radial growth of various test strains was recorded in four replications for each treatment. Strain A-15 developed a colony with a maximum diameter of (83.45 mm) on malt extract agar medium. Belgium-2 (check) strain measured a minimum (26.55 mm) colony diameter on oat meal agar medium. *Agaricus bisporus* test strains were cultured for 21 days at a variety of temperatures between 10 and 35 °C. Maximum growth of all the test strains including check (Belgium-2) was recorded at 25 °C (69.56 mm). Minimum growth of all the test strain including check (Belgium- 2) was recorded at 35 °C (11.79 mm). Temperature of 25 °C was found the best for the growth of all the test strains. Maximum length of cap was observed in strain A-15 (5.05 cm) followed by strain U-3 (4.78 cm), S-11 (4.28 cm) and Delta-N (4.05 cm) and minimum was taken in strain Belgium- 2 (check) (3.15 cm). Among the various test strains U-3 yielded maximum 15.08 kg/100 kg of compost. Strain A-15 having best desirable morphological characteristics with highest length of stalk 3.45 cm, width of stalk 3.03cm width of mushroom cap 4.73cm and length of mushroom cap 5.03 cm.

Keywords: *Agaricus bisporus*, strains, agar medium, mycelium growth

Introduction
Agaricus bisporus commonly known as white button mushroom is an edible fungus belongs to phylum Basidiomycota, class Basidiomycetes, order Agaricales and family Agaricaceae. *Agaricus bisporus* also known as khumbi and European mushroom. They are an excellent, nutrient-dense, significant source of medicine, and non-traditional source of human nourishment. A good source of vegetable protein, mushrooms are fleshy, edible fungi that also contain the majority of the essential amino acids, minerals, and vitamins. Their usage as food and medicine was first mentioned in the Vedas, an ancient work of Indian literature, around 3000 BC. While Chinese referred to it as a "elixir of life" and thought it to be a material that could cure all diseases, Greeks referred to it as "Food of God" (Singh *et al*., 2000) [12]. They have a lot of fiber in them. They also include high levels of potassium, copper, and phosphorus, low levels of sodium and iron, and good amounts of vitamin C, B complex, B-12, thiamine, riboflavin, niacin, and folic acid. There are close to 80 species of mushrooms that have been experimentally grown on diverse substrates, only a small number of which are grown commercially in various regions of the world (Singh and Mishra, 2010) [13]. There are 14,000 identified species of mushrooms. Of these, 7,000 are thought to have some degree of culinary quality, and over 3,000 species from 31 genera are considered to be great edibles. Only 200 of them have been successfully produced experimentally, 100 have been economically cultivated, about 60 have been commercially cultivated, and roughly 10 have attained industrial scale production in various nations (Sharma *et al*., 2007) [11]. *Agaricus bisporus* ranks highest among these, generating over a third of the current estimated global mushroom production of over 34,12,392 tons (Wakchaure, 2016) [16]. The most widely farmed edible mushroom species worldwide is *Agaricus bisporus*, also known as the white button mushroom. In addition to being grown for food, the white button mushroom has the potential to yield compounds that are both therapeutic and health-protective (Adams *et al*., 2008) [1]. The application of *Agaricus bisporus* in the bioconversion of agricultural and industrial lignocellulose waste appears promising as a lignin decomposer fungus (Stoknes *et al*., 2008) [14].

The goal of the current experiment was to assess the potential of several *Agaricus bisporus* strains grown in various growing conditions.

Materials and Methods

The Department of Plant Pathology at Dev Bhoomi Uttarakhand University in Dehradun's lab did study on the evaluation of various strains of button mushrooms for their cultural, morphological, and yield attributes. The current investigations were conducted between 2022 and 2023. *Agaricus bisporus* strains Delta-D, Delta-N, A-15, U-3, MC-465, S-11, and Belgium-2 (check) were the seven strains that were assessed.

The details of Materials and Methods for carrying out the present studies are given below under the following heads.

A) Purchasing, growing, and maintaining cultures of diverse strains Source of the Culture

Seven *Agaricus bisporus* strains were purchased: S-11 and U-3 from the Directorate of Mushroom Research at Chambaghat, Solan (H.P), and strains Delta-D, Delta-N, A-15, MC-465, and Belgium-2 from the Mushroom Research and Training Centre, GBPUAT Pantnagar. These strains' cultures were multiplied on potato dextrose agar medium at a temperature of 25 °C and periodically subcultured every three weeks.

a) Maintenance of Culture

The culture of *Agaricus bisporus viz*. strain Delta-D, Delta-N, A-15, U-3, MC-465, S-11 and Belgium-2 were stored at 4 °C and sub cultured regularly at an interval of three weeks. The 5–6 mm diameter mycelia agar chunks were cut and removed from mother culture slants, then transferred to new agar slants.

Effect of culture media, pH, and temperature on mycelium growth of various strain

The study effect of culture media, pH and temperature were conducted to understand in detail, which culture media pH and temperature were best for growing of mycelium growth of various test strain of *Agaricus bisporus viz*. Delta-D, Delta-N, A-15, U-3, MC-465, S-11 and Belgium-2.

a) **Sterilization**

Different media were sterilized in an autoclave for 20 minutes at 15 psi, and all the glassware was sterilized in an electric oven for 2 hours at 180 °C. The cork borer and inoculation needle were initially flame sterilized and then utilized following a thorough cooling down.

b) Incubation

Petri plates with basal medium and inocula of several test strains of *Agaricus bisporus* were cultured in a B.O.D incubator for 21 days at 25 °C.

c) Selection of solid medium

The best medium for mycelium development was chosen using five solid media. The various solid media's composition and preparation techniques were the same as those listed by Tutie (1969) [15]. Agar at a concentration of 2% was used to solidify various solid mediums. The best solid medium found was used for more research. The data were gathered so that general statistical inferences might be drawn from them.

d) Effect of temperature

Petri plates with malt extract agar medium and inoculums of several test strains, including MC-465, A-15, S-11, U3, Delta-N, and Delta-D, were incubated at a range of temperatures, including 10, 15, 20, 25, and 35 °C in various incubators. Data were statistically analyzed after each treatment was repeated four times.

e) Effect of various pH levels hydrogen ion concentration

In this experiment, malt extract agar medium was incubated at 25 °C for 21 days while inoculums of various test strains were adjusted to pH levels of 4.0, 4.5, 5.0, 5.5, 6.0, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, and 10. Four copies of each treatment were performed. A statistical analysis was performed on the data that was collected.

f) Observations

1. Mycelium growth (mm) on various solid media.
2. Mycelium diameter (mm) at various temperatures on malt extract agar medium.
3. Mycelium diameter (mm) at various pH levels on malt extract agar medium.

C) Cultural characteristics of various strain

a) Preparing Ready for Spawn

Substrates included wheat grains. The wheat grains were carefully cleaned before being soaked over the night. Dead grains and those that were afloat on the water's surface were taken out. The grains were rinsed once more the next day and cooked in tap water for at least 30 minutes. In order to prevent the grains from rupturing, care was taken not to overboil them.

The grains were given time to cool after the extra water was poured out. The grains were mixed with calcium carbonate and gypsum in a 1:3 ratio, and the glass milk bottles were then filled to 2/3 of their capacity. These bottles were correctly sealed with non-absorbent cotton before being autoclaved for two hours at 22 psi pressure. These bottles were immediately moved to the inoculation room after cooling down, and they were exposed to UV light for an hour to help with surface infections. 25 bottles of spawn were inoculated with one bottle of mother culture and then incubated at 25 °C for 15-20 days, or until the test strains' mycelium had fully impregnated the grains. For future usage, the bottles were kept in the refrigerator at a temperature of 2-4 °C.

b. Preparation of compost

The composition formula and method of preparation were the same as described by Garcha (1984) [7]. Wheat straw-based composts of different periods of termination and turning schedules were prepared by long method of composting.

Table 1: Formulation of compost

Ingredients	Quantity
Wheat straw	600 Kg
Wheat bran	60 Kg
Urea	6 Kg
Gypsum	60 Kg
Calcium ammonium nitrate	18 Kg
Single super phosphate	12 Kg
Molasses	10 litre

b) Observations

1. The number of days it takes mycelium to completely encase a wheat grain.
2. Wheat grain mycelium growth type.

D) Assessment of the test strain's ability to produce fruit and other morphological characteristics of fruiting bodies.

All of the test strains that were acquired were subjected to an evaluation trial for yield and other morphological features, which was set up in a completely randomized block design with four replications per treatment.

a) Spawn and Fill

Each polythene bag (18" x 18") contained 7 kilograms of fresh compost. Approximately 0.8% of spawn made from wheat grains was produced by spawning. These spawned sacks were covered with newspaper sheets, and the newspapers were then promptly sprayed with formalin (2%). At the time of spawning, measurements of the compost's moisture content, pH, and temperature were made.

b) Spawn Run

The spawn running period was 12-15 days; temperatures as well as relative humidity were maintained around 25 °C and 85 per cent, respectively. Little or no fresh air was supplied during this period (Kneebone, 1965) [9].

c) Management of casing and crops

Fully spawn run sacks were produced with casing soil that was 4 cm thick, appropriately sterilized and moist, and composed of garden soil and farmyard manure that was two to three years old in a (1:1) v/v ratio. Until pin head formation, relative humidity was kept between 85 and 90 percent; at this point, the bags were liberally watered to start the flush. Throughout the cropping time, the temperature was gradually dropped and kept between 14 and 18 °C, and the amount of fresh air allowed to enter was gradually increased.

d) Picking

Early in the morning, mushrooms were harvested using a mild twist to avoid damaging the young, developing mushrooms and leaving behind broken stumps in the beds. In order to prevent soil from sticking to the mushrooms, mushrooms were sliced at the soil level. At every harvest, mushrooms were selected, cut off, counted, and weighed from each bag. Mushrooms were selected when they were at a middle state of development and the veil was thin but still there. Up to sixty days following the first harvest, yield was recorded. According to Fritsche (1981) [6], twenty fruit bodies from each replication were used to record the morphological parameters of closed fruit bodies for each strain.

e) Observations

1. Daily room temperature and humidity during cropping period.
2. Different parameters of compost material like pH, moisture content and colour.
3. Days required for pin head formation.
4. Days required for button formation.
5. Total number of fruiting body per bag.
6. Weight of individual fruit body (g)
7. Stalk length and width (in cm).
8. The dimensions of the mushroom top in cm.
9. The overall yield of mushrooms (kg/q of compost).

(E) Statistical approach

Where necessary, statistical analysis of the recorded data was performed. By using the Complete Randomized Design (CRD) and Factorial Complete Randomized Design (FCRD), the differences between treatments were evaluated for significance. Using the MS-Excel, OPSTAT, and STPR 2.0 software, the experimental results are presented when necessary with the aid of tables and photos. The methods used to interpret the results and the design of the yield experiment were the same as those outlined by Lambert (1934) [10], Edwards (1947) [5], and Gomez and Gomez (1983) [8]. The approach and formula below were used to estimate various statistical parameters.

Table 2: Using a Complete Randomized Design (CRD) analysis of variance

Origin of the Variation	The extent of freedom	Total Squares	Mean squared	variation ratio (V.R.)
Replication (r)	r-1	Sr	Sr/(r-1) =Mr	Mr/Me
Treatments (t)	t-1	St	Sr/(t-1) = Ms	Ms/Me
Error (e)	(r-1) (r-1)	Se	Se/(r-1) (t-1) =Me	

Where,
r = Replications Percentage
t = The number of procedures
Sr = Sum of squares resulting from replications
St = Sum of squares as a result of treatments
Se = Sum of squares resulting from mistake
Mr = Mean Squares Resulting from Replications Mt is the average squared effect of the therapies. Me stands for Mean Square Error.

The tabulated F-value and the calculated F-value were compared. When the F-test indicated that an input was superior to the others, the crucial difference was determined. The crucial differences and standard error were computed as follows:

$SE\ (m) = Me / r$ $SE\ (d) \pm = \sqrt{Me/r\ 2}$

$CD\ (0.05) = S.E.\ (d) \times t\ (0.05)\ (r-1)\ (t-1)\ df$

Where,
SE (m)±= Standard error of mean SE (d)±= Standard error of difference
CD (0.05) = Critical difference at 5 per cent level of significance

Table 3: Analysis of variance for Factorial Complete Randomized Design (FCRD)

Source of Variation	Degree of Freedom	Sum of Squares	Mean sum of Squares	Variance ratio (V.R)
Factor	a-1	SSA	SSA(a-1)	MSA/MSE
Factor	b-1	SSB	SSB/(b-1)	MSB/MSE
Interaction	ab-1	SSAB	SSAB/(ab-1)	MSAB/MSE
Error	ab(r-1)	SSE	SSE/ab(r-1)	
Total	rab-1	TSS	TSS(r-1)	

Where,
r = Number of replications
a = Number of levels of factor A

b= Number of levels of factor B
ab = total number of interactions between factor A and factor BSSA = Sum of squares due to Factor A
SSB = Sum of squares due to Factor B
SSAB = Sum of squares due to interaction Factor A x B SSE = Sum of squares due to error
MSA = Mean sum of squares due to factor A
MSB = Mean sum of squares due to factor B
MSAB = Mean sum of squares due to interaction A x B MSE = Mean sum of squares due to error.

The tabulated F-value and the calculated F-value were compared. When the F-test indicated that an input was superior to the others, the crucial difference was determined. The crucial differences and standard error were computed as follows:

SE (m) equals MSE/r, and SE (d) equals 2MSE/r.CD (0.05) = S.E. (d) x t (0.05) (r-1) (t-1)

Results and Discussion

A) Effect of culture media

All strains, including the control (Belgium-2), were able to grow their colonies to the largest diameter on Malt extract agar medium (70.72 mm), which was followed by Potato dextrose agar media (63.99 mm) and Wheat extract agar medium (61.22 mm). Comparing different media, the minimum (33.89 mm) colony diameter was supported by oat meal agar medium after 21 days.

Regarding colony diameter in various media, strain A-15 recorded the largest colony diameter (64.94 mm), which was statistically comparable to strain U-3's (64.34 mm), while strain Bel-2's (41.31 mm) was the smallest.

Table 4: Mycelium growth (mm) of different test strain of *Agaricus bisporus* on various solid media

Sr. No.	Strains(S)	Colony diameter (mm) of different test strain after 21 days (M)					Mean
		Malt extract agar	Potato dextrose agar	Wheat extract agar	Corn meal agar	Oat Meal agar	
T_1	Delta-D	70.60	55.50	60.93	39.60	35.55	52.44
T_2	Delta-N	69.85	68.93	49.68	38.63	30.65	51.42
T_3	A-15	83.45	71.35	81.25	50.60	38.05	64.94
T_4	U-3	80.35	69.50	75.88	55.40	40.55	64.34
T_5	MC-465	65.83	60.45	46.85	35.63	28.78	47.54
T_6	S-11	74.20	73.58	68.35	45.45	37.08	59.73
T_7	Bel-2(check)	50.73	49.20	45.60	34.13	26.55	41.31
	Mean	70.72	63.99	61.22	43.63	33.89	
						S.E.(d)	SD(0.05)
			Strains (S)			0.38	1.10
			Medium(M)			0.29	0.83
			SxM			0.77	2.27

The interaction of multiple test strains with various solid media revealed that strain A-15 on malt extract agar medium developed the largest colony diameter (83.45 mm), followed by strain U-3 (80.35 mm) on the same medium. Belgium-2 (check) strain measured a minimum (26.55 mm) colony diameter on oat meal agar medium. All of the test strains of *Agaricus bisporus*, including the control (Belgium-2), flourished on the malt extract agar medium before flourishing on the potato dextrose agar medium.

B) Effect of temperature

Maximum growth was observed for all test strains, including the control (Belgium-2), at 25 °C (69.56 mm), then at 20 °C and 15 °C. At 35 °C, all test strains, including the control (Belgium- 2), showed the smallest growth (11.79 mm). All of the test strains were shown to grow best at a temperature of 25 oC. After 21 days and at various temperatures, strain U-3 (40.23 mm) and strain A-15 (42.26 mm) had the largest colony diameters. Strain Belgium-2 had the smallest mycelium growth measured (31.94 mm). According to the interaction investigation, strain A-15 recorded the largest colony diameter (81.20 mm) at 25 °C, followed by strain U-3 (80.18 mm) at 250 °C. Strain Belgium-2 (10.08 mm) was the minimum mycelium growth at 35 °C.

Table 5: *Agaricus bisporus* test strain extract mycelium growth (mm) of various strains at various temperatures on malt

Sr. No.	Strains (S)	During 21 days, the colony diameter (mm) of several test strains (T)						Mean
		10°	15°	20°	25°	30°	35°	
T_1	Delta-D	13.20	42.08	50.30	60.15	19.13	10.15	31.98
T_2	Delta-N	14.00	46.30	53.10	72.05	27.25	12.00	37.45
T_3	A-15	19.50	52.60	56.05	81.20	30.08	14.13	42.26
T_4	U-3	16.38	47.28	57.30	80.18	28.10	12.10	40.23
T_5	MC-465	15.13	46.18	55.10	69.03	25.10	11.03	36.93
T_6	S-11	15.03	43.13	53.08	68.15	20.10	13.05	35.43
T_7	Bel-2(check)	13.05	41.20	50.15	59.15	18.05	10.08	31.94
	Mean	15.37	45.54	54.14	69.56	24.68	11.79	
							S.E.(d)	CD (0.05)
			Strains (S)				0.24	0.43
			Medium (M)				0.12	0.20
			SxT				0.48	1.73

C) Effect of pH level and Hydrogen Ion Concentration

With N/10 HCl or N/10 NaOH, the pH of the base medium was changed to accommodate ranges of pH from 4.0 to 10.0. For each treatment, four replications were preserved. After 21 days of incubation at 25 °C, the colony diameter of many strains, including the check (Bel-2), was measured.

The data in Table 6 demonstrated that, in comparison to the control, all treatments significantly boost mycelium growth at various pH levels. After 21 days, pH 6.0 (58.53 mm) was recorded as the colony's maximum diameter (70.27 mm). All of the test strains, including the control (Bel-2) strain, measured a minimum (2.06 mm) colony diameter at pH 10.0. Regardless of pH, strain A-15 (36.46 mm) and strain U-3 (34.92 mm) reported the largest colony diameters. Bel-2 strain has a minimum colony diameter of (29.63 mm) (check). The interaction of various hydrogen ion concentrations with several test strains, including the control (Bel-2), showed that strain A-15 at a pH of 6.5 recorded the largest colony diameter (74.10 mm), followed by strain U-3 at the same pH level (72.05 mm). Bel-2 (check) strain measured a minimum colony diameter of 1.00 mm at pH 10.

Table 6: Different test strains of *Agaricus bisporus* mycelium growth (mm) on malt extract agar medium at various pH values. Different test strains colony diameter (mm) after 21 days (pH).

Sr. No.	Strains (S)	During 21 days, the colony diameter (mm) of several test strains (T)													Mean
		4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	
T_1	Delta-D	25.05	27.25	33.15	35.15	58.15	70.15	55.18	53.10	26.18	20.00	11.05	2.03	1.15	32.13
T_2	Delta-N	24.05	26.13	37.08	35.23	58.03	71.13	59.13	56.08	25.03	19.13	16.03	3.08	2.69	34.29
T_3	A-15	27.28	28.10	38.13	40.10	61.18	74.10	60.03	61.18	31.10	24.05	17.10	8.13	3.41	36.46
T_4	U-3	25.08	27.08	35.03	37.13	63.08	72.05	63.18	60.13	27.08	21.18	14.18	6.15	2.58	34.92
T_5	MC-465	23.05	22.35	34.08	35.20	55.13	70.15	56.03	53.05	24.13	16.10	13.08	2.05	1.33	31.00
T_6	S-11	22.00	25.25	37.98	36.08	60.05	69.13	56.15	56.08	16.10	20.10	15.07	5.10	2.23	33.33
T_7	Bel-2(check)	21.15	22.18	32.10	33.18	54.05	65.13	54.25	52.15	20.10	13.03	10.08	1.10	1.00	29.63
	Mean	23.95	25.48	35.37	36.00	58.53	70.27	57.70	56.39	25.97	19.09	13.79	3.95	2.06	
														S.E.(d)	CD(0.05)
			Strains (S)											0.38	0.75
			Medium(M)											0.20	0.52
			SxpH											0.34	0.87

D) Effect of wheat grain spawn on the development of different strains of mycelia

On boiled wheat grain substrate, all test strains, including the control, grew well, and all treatments were shown to be significantly different from the control (table 7). However, the rates of growth varied slightly depending on the types of growth. All of the test strains had strandy type growth that varied significantly in density. Strain Belgium-2 took the absolute minimum amount of time (14.25 days) to colonize the complete substrate (check). Strain MC-465 recorded the longest time (20.38 days) to completely cover the grains.4.4 Time taken by the mycelium to cover the entire grains in days and types of mycelium growth on wheat grain substrate

Table 7: On boiled wheat grain substrate, all test strains, including the control, grew well, and all treatments were shown to be significantly different from the control

Sr. No.	Strains	Days required by the mycellum to completely cover the grains	Type of growth
T_1	Delta-D	16.65*±0.56	Strandy, less dense
T_2	Delta-N	18.75*±0.86	Strandy, not dense
T_3	A-15	15.05*±0.62	Strandy, less dense
T_4	U-3	17.23*±0.79	Strandy, not dense
T_5	MC-465	20.38*±0.89	Strandy, not dense
T_6	S-11	19.28*±0.70	Strandy, not dense
T_7	Bel-2(check)	14.25±0.99	Strandy, less dense
	S.E.(d)	1.11	
	C.D. (0.05)	2.3	

E) Evaluation of strains in terms of production efficiency

According to table 8's fruiting trial results, all treatments for colonization on compost were shown to be statistically significant when compared to check. Strain S-11 required the least amount of time to run spawn on compost (14.18 days). Strain Belgium-2(check) was found to last the longest (19.60 days), followed by strains A-15 (18.08 days), and MC-465 (17.25 days).

In contrast, the strain S-11 took the least amount of time in the case run (15.50 days), followed by U-3 (16.45 days). In pinhead formation, strain S-11 took the least amount of time (16.65 days), and strain A- 15 took the most time (21.88 days), which was statistically comparable to strain Belgium (21.20 days). The maximum time was taken by strain Belgium-2 (20.28 days), followed by strains A-15 (19.38 days) and MC-465 (18.58 days).

It is evident from the data in Table 8 that strain S-11 required significantly less time than strain Belgium-2 for spawning, case run, and pinhead formation to first harvest (18.28 days), second harvest (28.48 days), and third harvest (34.43 days), and that strain Belgium-2 required significantly more time than strain S-11 for first harvest (24.25 days), second harvest (35.65 days), and third harvest (44.00 days).

Table 8: Growth behaviour of the different strain of *Agaricus bisporus* on wheat straw-based compost (days) Strains

Sr. No.	Strains	Spawn runs ± S.E. (m)	Case run ± S.E.(m)	Pinhead Formation ± S.E.(m)	First Harvest ± S.E.(m)	Second Harvest ± S.E.(m)	Third Harvest ± S.E(m)
T_1	Delta-D	17.74*±0.88	17.92*±1.10	20.05*±0.24	21.23*±0.33	32.55*±0.67	43.65*±0.54
T_2	Delta-N	16.08*±0.75	17.20*±0.46	17.35*±0.69	20.30*±0.35	30.80*±.47	41.25*±0.68
T_3	A-15	18.08±0.48	19.38*±0.95	21.88*±0.59	22.60*±0.68	33.33*±0.96	40.65*±0.58
T_4	U-3	15.13*±0.48	16.45*±0.69	18.25*±0.23	19.80*±0.54	29.60*±0.63	39.85*±1.59
T_5	MC-465	17.25*±0.24	18.58*±0.64	20.60*±0.29	21.33*±0.59	31.78*±0.67	43.23*±0.52
T_6	S-11	14.18*±0.75	15.50*±0.58	16.65*±0.85	18.28*±0.79	28.48*±0.56	34.43*±0.77
T_7	Bel-2(check)	19.60*±0.35	20.28*±0.26	21.20*±0.67	24.25*±0.48	35.65*±0.62	44.00*±0.69
	S.E.(d)	0.85	1.02	0.84	0.79	0.95	1.40
	C.D. (0.05)	1.77	2.13	1.75	1.66	1.97	2.93

F) Assessment of high-yielding *Agaricus bisporus* strains

Statistical analysis of the data in Table 9 on the yield effectiveness of several strains of *Agaricus bisporus* showed that all treatments were significant when compared to the control. Maximum yield was recorded in strain U-3 (15.80 kg/q of compost) followed by the strain Delta-N (11.78 kg/q of compost) and strain A-15 (11.55 kg/q of compost). Minimum yield was recorded in strains Bel-2 (check) (5.63 kg/q of compost).

The strain U-3 generated the most fruiting bodies (1,287.98/q of compost), followed by the strains A-15 (1,210.45/q of compost) and the strain Delta-N (1,129.18/q of compost), while the strain Belgium-2 (check) produced the least fruiting bodies (643.88/q of compost). The fruiting body weight was found to be lowest in the case of strain Bel-2 (check) (7.88 g), but much higher in the case of strain U-3 (12.25 g), followed by strains S-11 (11.03 g) and Delta-N (10.40 g)

Table 9: Yield performance of different strain of *Agaricus bisporus*

Sr. No.	Strains	Yield of mushrooms (kg/q of compost) S.E.(m)	Amount of fruiting bodies per unit of compost S.E.(m)	Fruit body weight per individual (g) S.E.(m)
T1	Delta-D	8.43*±0.60	909.68*±29.72	9.25*±0.83
T2	Delta-N	11.78*±0.46	1,129.18*±36.62	10.40*±0.58
T3	A-15	11.55*±0.38	1,210.45*±17.12	9.83*±0.69
T4	U-3	15.80*±0.525	1,287.98*±17.48	12.25*±0.74
T5	MC-465	7.45*±0.366	896.90*±7.98	8.18*±0.34
T6	S-11	10.30*±0.426	974.28*±45.54	11.03*±0.23
T7	Bel-2(check)	5.63±0.333	643.88±22.48	7.88±0.72
	S.E.(d)	0.64	39.51	0.88
	C.D. (0.05)	1.33	82.73	1.84

*Significant at 5% level of significance compared with check

G) Differences in the morphology of various strains of *Agaricus bisporus*

According to the results shown in table 10, the strain A-15 (3.45 cm) had the longest stalk, followed by strain U-3 (3.00 cm), while strain Belgium-2 (check) had the shortest stalk (1.90 cm). While strain A-15 (3.03 cm) had the widest stalks, strain U-3 (2.78 cm) had the narrowest stalks, and strain Belgium-2 (check) (1.25 cm), which was statistically equivalent to Delta-D, had the narrowest stalks. The statistics also demonstrated that all treatments had results that were noticeably better than control. Strain A-15 (4.73 cm) had the widest cap, followed by strains U-3 (4.43 cm) and S-11 (4.05 cm), with strain Bel-2 (check) (2.60 cm) having the narrowest cap. Additionally, strain A-15 (5.05 cm) had the longest cap, followed by strains U-3 (4.78 cm), S-11 (4.28 cm), and Delta-N (4.05 cm), while strain Belgium- 2 (check) (3.15 cm) had the shortest. Additionally, data indicated that all of the treatments were statistically superior than check.

Table 10: Differences in the morphology of various strains of *Agaricus bisporus*

Sr. No.	Strains	Length of stalk (cm) ± S.E.(m)	Width of stalk (cm) ± S.E. (m)	Width of mushroom cap (cm) ± S.E.(m)	Length of mushroom cap (cm) ± S.E.(m)
T_1	Delta-D	2.33*±0.284	1.38*±0.175	3.33*±0.180	3.78*±0.295
T_2	Delta-N	2.80*±0.225	2.38*±0.210	3.68*±0.345	4.05*±0.155
T_3	A-15	3.45*±0.236	3.03*±0.354	4.73*±0.423	5.03*±0.388
T_4	U-3	3.00*±0.245	2.78*±0.419	4.43*±0.335	4.78±0.304
T_5	MC-465	2.00*±0.354	1.68*±0.403	2.90*±0.268	3.38*±0.253
T_6	S-11	2.28*±0.328	2.05*±0.240	4.05*±0.507	4.28*±0.250
T_7	Bel-2(check)	1.90±0.168	1.25*±0.296	2.60±0.420	3.15±0.253
	S.E.(d)	0.37	0.45	0.53	0.39
	C.D. (0.05)	0.75	0.93	1.09	0.83

*Significant at 5% level of significance compared with check

Conclusion

The investigations on various strains of *Agaricus bisporus* provided valuable insights into the cultural, morphological, and yield attributes of these mushrooms The findings highlighted the importance of selecting suitable growth media, maintaining optimal temperature and pH conditions,

and identifying strains with desirable characteristics for improved mushroom cultivation. These results can contribute to the advancement of button mushroom cultivation practices, leading to increased productivity and quality in the mushroom industry.

Several important conclusions may be made based on the results of the studies done during the 2022–2023 period on the evaluation of different strains of *Agaricus bisporus* (button mushroom) for their cultural, morphological, and yield features.

First, the study found that potato dextrose agar medium was the second best medium for growing the mycelia of various strains of *Agaricus bisporus* after malt extract agar medium. This suggests that the malt extract agar creates favorable conditions for the mushroom mycelium's growth and development.

Second, it was found that the development of the several investigated strains of *Agaricus bisporus* on malt extract agar medium was best at a temperature of 25 °C. According to this research, button mushrooms can grow to their full potential when the temperature is consistently kept at 25 °C.

Lastly, strain A-15 was identified as having the most desirable morphological characteristics, including a stalk length of 3.45 cm, a stalk width of 3.03 cm, a mushroom cap width of 4.73 cm, and a mushroom cap length of 5.03 cm. These characteristics make strain A-15 a promising candidate for its appealing appearance and potential market value.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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